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TESTS OF RADIO RECEIVING SETS. IV

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Note.- These tests were made by Messrs. J.L.Preston, Physicist, H.J.Walls, Assistant Electrical Engineer, H.F.Harmon (radio laboratory assistant, U.S.Department of Agriculture), and others, under the direction of J.H.Dellinger and L.E. Whittemore, chief and alternate chief, respectively, of the radio laboratory.

1. Purpose of Investigation

This pamphlet is the last of a series[1] of four giving the results of an investigation of the characteristics of radio receiving sets in 1921 and 1922. This particular number of the series gives the results of tests of seven electron-tube sets, some of them of frequency range from about 30 to 300 kilocycles and others from about 80 to 1700 kilocycles.

A person who has a desire to make use of the service which can be brought to him by radio broadcasting or other forms of radio service, but who has not the technical knowledge to make wise selection of his apparatus, has been almost entirely without information as to the characteristics which determine the usefulness of a radio receiving set and the way in which these characteristics are expressed.

The Bureau of Agricultural Economics of the Department of Agriculture requested the assistance of the Bureau of Standards of the Department of Commerce on this problem, in connection with the reception of crop, market and weather reports which that Department was sending out through radio stations of the Post Office and Navy Departments and through public and private broadcasting stations.[2]

No consideration has been given to the possible existence of any patents which might cover devices or circuits used in any of the apparatus described. The Bureau of Standards can not give authoritative information concerning the patent situation with respect to a particular device.

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[1] No. I of the series (LC 90) gave the results of tests of five regenerative sets for continuous-wave reception, of frequency range from about 40 to 1200 kilocycles. No. II (LC 93) gave the results of tests of nine crystal-detector sets, of frequency range from about 200 to 1700 kilcycles. No. III (LC 102) gave the results of tests of thirteen electron-tube sets suitable for broadcast reception, some with and some without audio-frequency amplification, of frequency range from about 300 to 1700 kilocycles. Copies of these earlier pamphlets are in general no longer available for distribution, but may be consulted at the Bureau of Standards.

[2] For information as to schedules of transmission of Government reports by radio, reference should be made to the Radio Service Bulletin, a monthly publication of the Radio Inspection Service, Bureau of Navigation, Department of Commerce. This publication may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D.C., for 25 cents per year.

The particular receiving sets are referred to by arbitrary reference numbers rather than by a statement of the manufacturers' names or type numbers. It is hoped that the results given on these sets will be of assistance to designers and manufacturers in improving of radio receiving apparatus. It is also believed that purchasers will be directly aided in determining what features to look for in the selection of receiving sets.

The methods used in these tests are described in detail in a Technologic Paper in press entitled "Some methods of testing radio receiving sets," by J.L.Preston and L.C.F.Horle. When that paper is issued, it will be announced in the Radio Service Bulletin. It is appreciated that much remains to be done in the further development of the methods used, and this report and the others in this series are published with the expectation that they will be of assistance in the establishment of specifications and testing methods by the radio industry as a whole.

To the various manufacturers and individuals who have helped in this work through furnishing sets for test and in other ways, the Bureau expresses its thanks. Particular acknowledgment is due the Bureau of Agricultural Economics of the Department of Agriculture, which loaned assistants to carry on the laboratory work and cooperated in many other ways.

Receiving Sets Included in this Report.-- Seven receiving sets were included in the tests described in this report. These were made by five different manufacturers, and were received during the latter part of the year 1921. New and improved models of some of these are now on the market. For convenience in reference the following arbitrary numbers are used in designating the receiving sets.

1922-AA	1922-CC	1922-EE	1922-GG
1922-BB	1922-DD	1922-FF	

The circuit diagrams and other data on the sets are given below.

2. Outline of Tests Performed

After a preliminary performance test to determine whether the receiving set, as received, is in proper operating condition, the following examinations and tests were made (the tests are described in more detail in the Technologic Paper mentioned above):

a. Circuit diagrams.-- If diagrams have been submitted by the manufacturer, these are checked. When none are supplied, diagrams are made from the receiving set.

b. Circuit and panel arrangements.-- Inspection of the exterior arrangements of the receiving set and circuit is made.

c. Structural Details.-- The receiving set is examined for

ruggedness, quality of material, quality of component parts, and quality of workmanship.

In doing this, the device is given a very close inspection to determine the absolute and relative grades of materials from the mechanical viewpoint, with particular reference to the materials under mechanical strain, the materials and parts which are likely to change because of the effects of moisture and mechanical shock and those which are likely to wear in use.

d. Electrical inspection.-- The receiving set is examined to determine the qualities of its component materials from the electrical viewpoint, the care taken in working up these materials into component parts, and their disposition relative to one another. This inspection is made with special attention to the materials that constitute the high-voltage parts of the circuit, those which are under dielectric strain, and the protection of these parts from the effect of time and moisture.

e. Frequency (wave length) ranges.-- The receiving sets are calibrated when connected to an antenna having constants which are known and are approximately those met with in use. This frequency calibration allows the total frequency (wave length) range to be determined and also gives approximate data as to the settings of the variable controls for any frequency within the range of the set.

f. Vibration test.-- Thistest is designed to obtain information as to mechanical strength and ability to withstand shock in transportation. This information is obtained by fixing the receiving set on a vibrating machine which subjects it to shock and vibration simulating the shocks of transportation. After being subjected to this shaking and vibration for a short time the receiving set is taken from the vibrating machine and carefully inspected as to mechanical condition. This test indicates what weakness, if any, may be expected to develop in transportation or rough usage of the receiving set.

g. Sensitivity.-- This test is the determination of the magnitude of the response in the telephone receivers of the receiving set for a given voltage applied to the antenna.

h. Selectivity.-- This test is the determination of the ability of the receiving set to differentiate between signals of different frequencies.

i. Notes on operation.-- The receiving sets are connected to an antenna of measured constants and put into operation as specified by the manufacturer. The ease of operation, the precision and permanence of adjustment are noted.

3. Manufacturers' Specifications of Antenna, Frequency Range, Electron Tubes, and Telephone Receivers.

Receiving Set No.1922-AA.
Antenna not specified.
Frequency (wave length) range, 300 to 43.5 kilocycles per second (1000 to 6900 meters).
Electron tube, soft detector type.
Telephone receivers,-, 2000 ohms.

Receiving Set No. 1922-BB.
Antenna not specified.
Frequency (wave length) range, 300 to 25 kilocycles per second (1000 to 12,000 meters).
Electron tube, soft detector type.
Telephone receivers, -, 2000 ohms.

Receiving Set No. 1922-CC.
Antenna not specified.
Frequency (wave length) range, 2000 to 100 kilocycles per second (150 to 3000 meters).
Electron tube, soft detector type.
Telephone receivers not specified.

Receiving Set No. 1922-DD.
Antenna not specified.
Frequency (wave length) range not stated.
Electron tube, soft detector type.
Telephone receivers, -, 5000 ohms.

Receiving Set No. 1922-EE.
Antenna not specified.
Frequency (wave length) range not stated.
Electron tube not specified.
Telephone receivers not specified.

Receiving Set No. 1922-FF.
Antenna not specified.
Frequency (wave length) range not stated.
Electron tube not specified.
Telephone receivers not specified.

Receiving Set No. 1922-GG.
Antenna not specified.
Frequency (wave length) range, 1500 to 100 kilocycles per second (200 to 3000 meters).
Electron tube not specified.
Telephone receivers not specified.

4. Circuit Diagrams.

The circuit diagrams of the eight receiving sets included in this test are given in Figs. 1 to 7 inclusive.

5. Circuit and Panel Arrangements.

The several receiving sets discussed in this report differ widely in the arrangement of controls, type of circuit used, method of mounting parts, etc. In the brief descriptions given below, these characteristics are noted.

Receiving Set No. 1922-AA.--

This receiving set is of the single-circuit type and consists of a continuously-variable air condenser and two removable inductors of the lattice-wound type connected in series. All parts are mounted on a black laminated phenolic panel, 7 3/4 x 9½ inches, which in turn is secured to an oak cabinet 11 by 9 1/4 by 8½ inches. The panel has a dull finish, and all exposed metal parts are finished in dull nickel. Controls are provided on the panel for variable air condenser, for varying the coupling between the two series-connected inductors, for the filament current and for the variation of the plate voltage. The variable air condenser is equipped with a white celluloid dial mounted on the control knob and passing under a celluloid indicator mounted on the panel. No provision is made on this dial for frequency (wave length) calibration markings. A variable grid leak is mounted on the panel and protected by a nickeled brass cover. Binding posts are provided on the front of the panel for the antenna and ground connections, for the filament supply batteries and for the telephone receivers. These binding posts are of the composition insulated type.

Receiving Set No. 1922-BB.--

This receiving set which is of the two-circuit regenerative type, employs for tuning three removable inductors of the lattice-wound type, and a primary and a secondary variable air condenser. Regeneration is secured by inductive feedback. This set includes an electron tube detector and two stages of audio-frequency amplification. The whole is mounted on a series of four panels in a single oak cabinet 30 by 8 by 10 inches. Controls are provided for the two tuning condensers; for varying the coupling between the primary and secondary inductors and between the secondary and tickler inductors. Controls are also provided for the filament current and plate voltage of the detector tube and for the filament current of the two amplifier tubes. A switch is provided for connecting the antenna tuning condenser either in series or in parallel with the antenna inductor. Both condensers are provided with white celluloid dials which pass under indicators secured to the panel and are equipped with fine adjustment controls. No provision is made on the condenser dials for the addition of frequency (wave length) calibration markings.

Receiving Set No. 1922-CC.--
This receiving set is of a single-circuit regenerative type and consists of a variable air condenser in series with a tapped inductor. An electron tube detector is employed and regeneration is secured by inductive feedback. All parts are mounted on a black laminated phenolic panel 6 3/4 by 16 1/4 inches which is secured in an oak cabinet 7 1/4 by 7 by 17 inches. Controls are provided for the antenna circuit condenser, for the antenna circuit inductance, for regeneration, and for the filament current. Metal binding posts are provided on the panel for the connection of the antenna, the ground, the filament battery, plate battery and the telephone receivers. No slow variation of the antenna condenser is provided for, nor is there any provision made for frequency (wave length) calibration markings on the condenser dial.

Receiving Set No. 1922-DD.--
This receiving set is of the coupled-circuit type and consists of a tapped inductor and a variable air condenser connected in parallel in the antenna circuit, an inductive coupling between the antenna circuit and the secondary circuit which is made up of an inductor and a variable air condenser. An electron tube detector is employed. All parts are mounted on a black laminated phenolic panel 10½ by 10 inches which has a dull finish. The panel is mounted in a polished mahogany cabinet 10 3/4 by 10 1/4 by 10 inches. All exposed metal parts are finished in polished nickel. Controls are provided for varying the antenna inductance in both large and small steps, for the antenna and secondary circuit tuning condensers; for varying the coupling between primary and secondary, and for other circuit changes of doubtful utility. Polished nickel binding posts are provided on the panel for the connection of the antenna and ground, the filament and plate batteries, and the telephone receivers. Terminals are brought out for the connection of a variable inductor in the plate circuit. The condenser and coupling controls are provided with black moulded phenolic dials, but no index is provided on the panel for indicating the position of the dial relative to the panel, nor any method for frequency (wave length) calibration markings. The controls and binding posts are indiscriminately located on the panel. No markings are given on the panel to indicate what connections should be made to the binding posts nor what functions the controls perform. No stops are provided for the rotating switch arms.

Receiving Set No. 1922-EE.--
This receiving set is of the two-circuit regenerative type. The antenna circuit consists of an inductor of the lattice-wound type in series with a variable air condenser; the secondary circuit consists of a similar inductor in parallel with a variable air condenser. Inductive feedback is used to secure regeneration. The inductor in the plate circuit is shunted by a variable air condenser. All parts are mounted on a black laminated phenolic panel 12 by 15 inches, dull finished, and mounted in a mahogany

colored oak cabinet 12 by 15 by 9 inches. All exposed metal parts are finished in highly polished nickel. Controls are provided for the antenna circuit condenser, the secondary circuit condenser and the plate circuit condenser, as well as for the control of the coupling between the antenna and secondary circuits, and between the secondary and plate circuits. Terminals are provided on the front of the panel for the antenna, ground, filament and plate battery, and the telephone receivers. There are no fine adjustments provided on the condensers, nor is any provision made for the addition of frequency (wave length) calibration markings.

Receiving Set No. 1922-FF.--

This receiving set is of the single-circuit regenerative type with inductive coupling to the plate circuit. It consists of a continuously-variable air condenser, a tapped inductor, an electron-tube detector with necessary auxiliaries, and two stages of audio-frequency amplification. Regeneration is secured by inductive feedback. All parts are mounted on a black laminated phenolic panel which is secured to a polished soft wood cabinet. All exposed metal parts are finished in polished nickel. Controls are provided for the antenna condenser, the tapped antenna inductor; for regeneration and for the filament current. A filament ammeter is mounted on the panel together with two telephone jacks and binding posts for antenna, ground, filament and plate battery connections. A door is provided in the cabinet so that the electron tubes may be easily inserted in the sockets. The antenna circuit condenser carries an engraved and polished metal dial which passes over an index on the panel. No provision is made for the addition of frequency (wave length) calibration markings on the dial.

Receiving Set No. 1922-GG.--

This receiving set is of the single-circuit type and consists of a balanced variable air condenser and a tapped inductor. It is provided with an adjustable galena crystal detector and an adjusting buzzer. All parts are mounted on a black laminated phenolic panel which is secured to a polished mahogany cabinet. All exposed metal parts are finished in highly polished nickel. Controls are provided for the antenna circuit condenser; for the antenna circuit inductor; and for the transfer of the tuner from connection with the crystal detector to the external electron tube detector, for which binding posts are provided. All binding posts are finished in highly polished nickel and labelled by careful engraving on the panel. These binding posts provide for connection to the antenna, the ground, the buzzer battery, the telephones, the filament, the grid and the plate circuit of the electron tube detector. The condenser dial provides for the addition of calibration markings and is equipped with an index which passes over it, so that a frequency (wave length) calibration can be made and easily read for each value of inductance.

6. Structural Details.

Receiving Set No.1922-AA.-

Several types of insulating material are used in this receiving set. The panel is of the laminated phenolic type, the inductor mounting plugs, the control knobs and the binding posts of the moulded type, the tube socket base of a composition (probably a shellac compound), and the rheostat form of the moulded phenolic type. The condenser is built up of aluminum plates clamped between brass end plates. The moving plate system is carried in brass thrust bushings and insulated from the end plates by hard rubber washers. The inductors are wound with solid wire and are of the lattice-wound type secured to a moulded phenolic connecting plug. Connection is made to the movable coil receptacle through a flexible conductor, while connection to the movable plate system of the condenser and the contactor of the switch and the contactor of the filament rheostat is made through friction contacts. Interconnection between parts is made with a small copper wire, covered with impregnated cotton insulation, soldered to terminals. Much of the wiring is not supported but hangs loose.

Receiving Set No.1922-BB.-

The material of this receiving set is rather of a miscellaneous nature. The panels are made of laminated phenolic materials and are poorly engraved and finished. The coil mountings and the electron tube socket shells are of the moulded type, the latter showing weakness, while the condenser insulation is of hard rubber. The condensers are built up of aluminum plates supported between heavy brass end plates, which carry adjustable thrust bearings insulated from the end plates by means of hard rubber washers. The electrical connections between the several parts are made by means of copper wire, covered with varnished cambric tubing, and soldered to terminals. The connection to the moving parts of the filament rheostat and switches are made through sliding contacts, while the connections to the inductors are made through flexible conductors, and the connection to the variable condenser through the moving plate bearings. The tube sockets, which are made of moulded material, lack physical strength and are quite easily broken. The rheostats are made up of moulded phenolic forms with sufficient ventilation to prevent charring. The location of the binding posts on the several panels is such that the wiring between them is loose and unsightly.

Receiving Set No.1922-CC.-

The panel, the condenser end plates, the inductor form, the electron tube socket base and the condenser supports are of black laminated phenolic material, carefully machined and assembled. The condenser plates are of aluminum and built up into a balanced unit. The antenna inductor is wound of high-frequency cable covered with raw silk and impregnated with varnish. The plate circuit inductor is wound with solid wire on wood forms and impregnated with varnish. The connections to moving parts are made

through a flexible coiled copper conductor. Interconnecting wires are of bare tinned copper, held rigidly in position and securely soldered to terminals. The tube socket is well constructed and securely fastened to the panel; the fixed condensers are built up of copper foil with mica dielectric and thoroughly impregnated. The filament rheostat is mounted in a circular slot in the panel thus making it of rather rugged construction but one of very meager ventilation. Connection to the rheostat contactor is made through a rather loose bearing. The moving arm of the rheostat is not provided with stops.

Receiving Set No.1922-DD.-

The insulating materials which constitute parts of this receiving set are as follows: the panel is of laminated phenolic material, the condenser end plates are of a moulded material (probably a shellac compound), the rheostat form and electron tube socket base are of moulded material, and the inductor forms are of impregnated cardboard. The inductors are wound with rather fine solid wire and impregnated with varnish or shellac. The condensers are built up of extremely thin aluminum plates. All switches are without stops and those which have more than one contact are so designed as to allow of the short-circuiting of adjacent contacts by means of the contactor arm. Connection from the condenser, moving plate system, switches, rheostat contactor and secondary inductor, are made through very light friction contacts in which the contact resistance is likely to become very high, and no attempt has been made to secure and maintain good contact in these parts. Connections between the inductor and the inductor switches are made by means of the same fine wire which constitutes the inductor and these leads are carelessly soldered to the inductor switch studs. No insulation but that of the fine silk covering is present on these connections. All other interconnections, however, are made with extremely sturdy copper wire covered with rubber tubing and securely soldered to the terminals. The grid condenser is built up of tin foil and wax paper sheets and is of extremely cheap construction. The supporting brackets for the inductor are rather insecure. In general, it may be said that the materials and workmanship and general layout of this receiving set are of rather low grade and not to be recommended.

Receiving Set No.1922-EE.-

The dielectric materials in this receiving set, such as the panel, the condenser end plates, the coil supports, etc., are of rather miscellaneous nature. The panel is of black laminated phenolic material and the condenser end plates are of like material but poorly impregnated. The coil supports are of soft wood and the several insulating strips are of hard rubber. The inductors which are of the lattice-wound type have only a thin cardboard insulating tube support, and make contact through very light brass springs insecurely fastened to the coil supports by means of single escutcheon pins. Connection to the condenser moving plate systems is made by means of a copper friction spring, while connection to the moving coils is made through flexible conductors. The tube socket is securely fastened to the panel by means of sturdy copper supporting brackets, while the grid leak and grid condenser are supported by the connecting wires. All interconnecting wires are sturdy

uninsulated copper wire, carefully formed and spaced. The coil mounting supports are unusual in that they allow the simultaneous motion of the coil in several directions at once. They are, however, extremely light in construction.

Receiving Set No.1922-FF.-
In this receiving set the main panel and sub-panels, the inductor forms and the condenser and rheostat end plates are of the laminated phenolic material, carefully machined and fitted. The inductors are bankwound with high-frequency cable, the terminals being brought out to a connection panel integral with the inductor unit. The variable air condenser is built up of aluminum plates. The aluminum tube sockets are securely mounted on the sub-panel, supported by sturdy brass supporting angles. In the filament rheostat, the major portion of the resistance wire is extremely well ventilated. The amplifying transformers are very compact and securely mounted on the panel. All connections to moving parts, such as the variable condenser, movable plate system, the rheostat contactor, the inductor switch contactor and the tickler coil connection shaft are made through coiled phosphor bronze springs securely soldered at their ends. All interconnecting wires are covered with varnished cambric tubing and are securely soldered to the terminals at their ends.

Receiving Set No.1922-GG.-
The panel of this receiving set is of black laminated phenolic insulating material. The antenna inductor is wound of high-frequency cable on a cylindrical laminated phenolic form. The detector circuit inductor is wound of spaced solid wire on a similar form. The inductor switch arm is connected to the circuit through a phosphor bronze coil spring securely soldered. The condenser is built up of aluminum plates in two sections so as to be balanced, and mounted between laminated phenolic end plates. The connection between the moving plate system and the circuit is made by means of a coiled phosphor bronze spring securely soldered. The transfer switch is of the so-called "anti-capacity" type and is securely fastened to the panel. All interconnecting conductors are covered with varnished cambric tubing and securely soldered at their ends. The several parts of the receiving set are well located relative to one another.

7. Electrical Inspection.

Receiving Set No.1922-AA.-
The so-called "ultra audion" circuit is used in this receiving set and the diagram of connections is given in Fig.1. This circuit employs capacity coupling between the grid and plate circuits of the tube. Tuning is accomplished by the variation of the antenna circuit condenser, which, however, also controls the degree of regeneration. Thus it is impossible to control these two functions independently and impossible to secure maximum regeneration except by the control of filament currents. The tuning condenser is shunted by the "B" battery and telephone receivers.

Receiving Set No.1922-BB.-

The circuit of this receiving set, as shown in Fig.2, is of the usual two-circuit type with inductive feedback, except that it provides for the use of the antenna condenser, in series or in parallel with the antenna inductor. Tuning is accomplished by means of the primary and secondary variable air condensers, while regeneration is controlled by the motion of the feedback inductor relative to the secondary inductor. Grid rectification is employed. No attempt is made to provide against the accidental variation of the distributed capacity of the coils by the motion of the operator's body, since these are mounted directly above the condenser controlling rods. The method of interior connection of units is such that high voltage leads are closely parallel to the low voltage leads.

Receiving Set No.1922-CC.-

The circuit of this receiving set, as shown in Fig.3, is that of the usual single-circuit type with inductive coupling between the grid and plate circuits. The inductor is a three-layer bankwound coil, and provision is made for the reduction of loss due to resonant sections by the use of a short-circuit finger switch. Tuning is accomplished by the variation of the antenna condenser and inductor, while regeneration is secured by the variation of the coupling between the antenna and plate circuits. Grid rectification is employed.

Receiving Set. No.1922-DD.-

The circuit of this receiving set, as shown in Fig.4, is of the two-circuit type, but differs radically from the usual schemes of connection, in that the antenna condenser is connected in parallel with the antenna inductor, and that the provision for inductive loading of the secondary circuit is not made in the secondary circuit proper, but in the connection between the secondary circuit and the grid. Connection is provided between the plate of the detector tube and the ground terminal, the purpose of which is not clear.

Receiving Set No.1922-EE.-

The circuit of this receiving set, as shown in Fig.5, is the usual two-circuit type, except that provision is made for tuning the plate circuit. This requires the successive tuning of three circuits, and results in a lack of easy control of regeneration. The use of the removable inductors, however, is distinctly advantageous in so far as possible frequency (wave length) range and efficiency is concerned, but in this receiving set these advantages are partially offset by their comparative inaccessibility.

Receiving Set No.1922-FF.-

The circuit arrangement of this receiving set, as shown in Fig.7, is of the usual single-circuit type. The connection from the antenna is made directly to the tapped inductor from which connection is made to the ground through the tuning condenser Regeneration is accomplished by inductive coupling between the plate and antenna circuits. The filament rheostat is connected in series with the three tube filaments which are connected in parallel, while the filament ammeter is connected in series with the filament of one of the tubes. Tuning is accomplished by means

of the antenna condenser, and by the tapped antenna inductor. Grid rectification is employed.

Receiving Set No.1922-GG.-

The circuit of this receiving set, as shown in Fig.8, differs from the usual single-circuit type in that an aperiodic secondary circuit, connected to the crystal detector, is very closely coupled to the antenna inductor. The transfer switch which is provided for changing the connection to crystal or electron tube detector, makes possible the connection of this aperiodic secondary circuit to the crystal detector only. The usual single-circuit connection to the electron tube is employed. The tuning is accomplished by means of the antenna circuit series condenser, and by means of the variation of the antenna circuit inductor. No provision is made for the slow variation of the tuning condenser, nor for the change of the aperiodic secondary inductor.

8. Frequency (Wave Length) Ranges.

Tables 1 to 9 give the frequency (wave length) ranges and overlaps of the several receiving sets included in this report. The percentage overlap is computed as the ratio of the overlap frequency band to the greater of the two frequencies of which it is the difference.

Table 1.--Frequency (wave length) Ranges of Receiving Set No.1922-AA.

Inductor	Condenser						
	Minimum		Maximum		Overlap		
	Frequency (kc) f	Wave length meters	Frequency (kc) f	Wave length meters	Frequency (kc) f	Wave length meters	Percen
DL-100T and 150T	291.0	1030.	166.0	1800	56.0	450.	25
150T & 200T	222.0	1350.	122.0	2460.	41.0	620.	25
200T & 250T	163.0	1840.	90.0	3320.	30.0	820.	25
250T & 300T	120.0	2500.	64.0	4670.	28.5	1440.	31
300T & 400T	92.5	3230.	49.5	6060.	42.0	2450.	40
500T & 600T	51.5	5810.	29.2	1025.			

Table 2.
Frequency (Wave Length) Ranges of Receiving Set No. 1922-BB.

	Primary						
	Condenser						
Inductor	Minimum		Maximum		Overlap		
	Frequency Kilocycles per second f	Wave Length Meters	Frequency Kilocycles per second f	Wave Length Meters	Kilocycles	Meters	Perce
DL- 200	373.0	800	180.0	1660.	27.0	215.	13
300	207.0	1445	94.0	3185.	–	–	–
600	80.5	3700.	38.1	7840.	16.2	2340.	30
1000	54.3	5500	26.5	11350.	–	–	–
	Secondary						
DL- 150	479.0	625	154.0	1990.	100.5	810.	40
350	254.5	1180	74.5	4000.	43.0	1440.	37
500	117.5	2560	34.7	8600	41.3	4670	54
600	7610	3930	23.45	11800			

Table 3.

Frequency (Wave Length) Ranges of
Receiving Set No. 1922-CC

Inductor	Condenser				Overlap		
	Minimum		Maximum				
	Frequency Kilocycles per second f	Wave Length Meters	Frequency Kilocycles per Second f	Wave Length Meters	Kilocycles	Meters	Percent
1	1705.0	175.	905.0	330	260.0	72.	22
2	1165.0	258.	595.0	504	180.0	121.	23
3	775.0	383.	427.0	698	133.0	164.	24
4	560.0	534.	305.0	980	122.0	282.	29
5	427.0	698.0	207.0	1445	115.0	517.	36
6	322.0	928.	176.0	1700	96.0	595.	35
7	272.0	1105.	138.5	2160	101.5	910.	42
8	240.0	1250.	122.0	2455.	73.0	920.	37
9	195.0	1535.	102.0	2935	73.0	1230.	42
10	175.0	1705.	95.0	3150			

Table 4

Frequency (Wave Length) Ranges of Receiving Set No. 1922-DD.

Primary Inductor	Condenser				Overlap		
	Minimum		Maximum				
	Frequency Kilocycles per second f	Wave Length Meters	Frequency Kilocycles per second f	Wave Length Meters	Kilo-cycles	Meters	Percent
1	545.0	548	352.0	846	111.0	202	24.0
2	463.0	644	259.0	1158	103.0	332	28.5
3	362.0	826	207.0	1445.	101.0	473	32.8
4	308.0	972	208.0	1440	61.0	320	22.7
5	269.0	1120	158.5	1895	80.5	640	33.6
6	239.0	1255	140.5	2130	73.5	730.	34.3
7	214.0	1400	128.0	2345	68.0	815	34.7
8	196.0	1530	116.0	2590	60.0	890	34.1
9	176.0	1700	108.0	2780	56.0	960	34.1
10	164.0	1820	98.5	3040	40.0	880	28.9
11	138.5	2160	92.0	3250	27.5	735	23.0
12	119.5	2515	73.0	4100	41.0	1460	35.9
13	114.0	2640	68.5	4360	35.0	1465	33.8
14	103.5	2895.0	64.0	4660	35.0	1640	35.3
15	99.0	3020	63.5	4730	33.5	1640	34.5
16	97.0	3090	61.5	4850	35.0	1745	36.3
17	96.5	3105	59.0	5060			
Secondary Inductor	362.0	826	54.3	5500			

Table 5.

Frequency (Wave Length) Ranges of Receiving Set No. 1922-EE

Inductor	Condenser Minimum Frequency Kilocycles per second f	Condenser Minimum Wave Length Meters	Condenser Maximum Frequency Kilocycles per second f	Condenser Maximum Wave Length Meters	Overlap Kilocycles	Overlap Meters	Overlap Percent
25T	2290.0	132	1200.0	250.	550.0	80	31
35T	1750.0	170	875.0	340	255.0	74	22
50T	1130.0	266	675.0	442	215.0	107	24
75T	890.0	335	470.0	635	315.0	255	40
100T	785.0	380	362.0	825	181.0	275	33
150T	543.0	550	222.0	1330	151.0	530	40
200T	373.0	800	168.0	1775	111.0	700	40
250T	279.0	1075	136.0	2200	131.0	1075	49
300T	267.0	1125	115.5	2600	94.5	1170	45
400T	210.0	1430	87.5	3410	83.5	1660	49
500T	171.0	1750	74.0	4150	78.5	2190	53
600T	152.5	1960	61.0	4910	56.0	2340	48
750T	117.0	2570	45.5	6570	40.0	3075	47
1000T	85.5	3495	33.8	8850	24.7	3710	42
1250T	58.5	5140	23.1	13000	26.4	6900	53
1500T	49.5	6100	20.0	15000			

Table 6

Frequency (Wave Length) Ranges of Receiving Set No. 1922-EE

Secondary

Inductor	Condenser				Overlap		
	Minimum		Maximum				
	Frequency Kilocycles per second f	Wave Length Meters	Frequency Kilocycles per second f	Wave Length Meters	Kilo-cycles	Meters	Percent
25T	2500.0	120	1200.0	250	615.0	85	34
35T	1815.0	165	840.0	355	660.0	155	44
50T	1500.0	200	642.0	465	358.0	165	36
75T	1000.0	300	427.0	700	283.0	280	40
100T	710.0	420	315.0	950	215.0	385	41
150T	530.0	565	206.5	1450	178.5	675	46
200T	385.0	775	157.5	1900	142.5	900	47
250T	300.0	1000	125.0	2400	136.0	1250	52
300T	261.0	1150	107.5	2800	85.5	1250	44
400T	193.0	1550	80.5	3700	75.0	1775	48
500T	155.5	1925	62.5	4800	65.5	2455	51
600T	128.0	2345	52.5	5700	50.0	2775	49
750T	102.5	2925	39.3	7600	27.7	3150	41
1000T	67.0	4450	28.6	10500	20.4	4400	42
1250T	49.0	6100	20.0	15000	16.5	7250	48
1500T	38.5	7750	15.0	20000			

Table 7

Frequency (Wave Length) Ranges of Receiving Set No.1922-FF

Inductor	Condenser				Overlap		
	Minimum		Maximum				
	Frequency Kilocycles per second f	Wave Length Meters	Frequency Kilocycles per second f	Wave Length Meters	Kilo-cycles	Meters	Percent
1	1500.0	200	560.0	535	580.0	271	51
2	1140.0	264	421.0	710	169.0	205	29
3	590.0	505	295.0	1015	135.0	320	31
4	430.0	695	207.0	1450	95.0	460	31
5	302.0	990	147.5	2030	74.5	680	33
6	222.0	1350	107.0	2800	61.0	1020	36
7	168.0	1780	84.0	3550	32.0	960	28
8	116.0	2590	59.5	5050			

Table 8

Frequency (Wave Length) Ranges of Receiving Set No. 1922-GG.

Coupled Crystal Detector							
Inductor	Condenser				Overlap		
	Minimum		Maximum				
	Frequency Kilocycles per second f	Wave Length Meters	Frequency Kilocycles per second f	Wave Length Meters	Kilo-cycles	Meters	Percent
1	1705	175	725	412	605	189	46
2	1330	223	520	576	660	322	56
3	1180	254	387	770	188	252	33
4	575	518	295	1016	168	372	36
5	463	644	208	1440	131	562	39
6	339	878	144	2070	117	924	45
7	261	1146	110	2730	112	1380	50
8	222	1350	75.5	3960			

Table 9

Summary of Frequency (Wave Length) Ranges

Receiving Set No.	Damped or modulated wave reception		Continuous wave reception		Specified Ranges	
	Frequency Kilocycles per second f	Wave Length Meters	Frequency Kilocycles per second f	Wave Length Meters	Frequency Kilocycles per second f	Wave Length Meters
1922-AA	-	-	201 to 23.2	1031 to 10250	300 to 43.2	1000 to 6900
1922-BB	373 to 26.5	800 to 11350	373 to 26.5	800 to 11350	300 to 24	1000 to 12500
1922-CC	1705 to 95	175 to 3150	1500 to 600	200 to 500	2000 to 95	150 to 3150
1922-DD	362 to 54.2	826 to 5500	362 to 120	826 to 2500	-	-
1922-EE	2290 to 20	132 to 15000	1500 to 50	200 to 10000	-	-
1922-FF	1500 to 59	200 to 5050	1500 to 850	200 to 3500	-	-
1922-GG	1705 to 75.5	175 to 5960	-	-	1500 to 100	200 to 3000

9, Vibration Test

Receiving Set No. 1922-AA.-

At the end of a fifteen-minute vibration test it was found that this receiving set was in good condition, except for the loosening of the condenser counterweights. It was necessary to reset and tighten these counterweights before the receiving set could be satisfactorily operated.

Receiving Set No. 1922-BB.-

At the end of a fifteen-minute vibration test, it was found that this receiving set was in good condition except for the loosening of the condenser counterweights, and the disarrangement of the "B" battery and a number of flexible connections.

Receiving Set No. 1922-CC.-

At the end of a fifteen-minute vibration test it was found that this receiving set was in the same condition as before the test was begun.

Receiving Set No. 1922-DD.-

At the end of a fifteen-minute vibration test, it was found that the four legs supporting the primary inductor had become free, due to certain nuts shaking loose. This allowed the inductor to swing free, breaking several leads to the primary taps. The secondary inductor also became unsupported, breaking its sliding contacts and opening the circuit so that reception of signals was impossible. It was necessary to completely overhaul the receiving set before it could be used for the reception of signals.

Receiving Set No. 1922-EE.-

At the end of a fifteen-minute vibration test, it was found that this receiving set was in the same condition as before the test was begun.

Receiving Set No. 1922-FF.-

At the end of a fifteen-minute vibration test, it was found that this receiving set was in the same condition as before the test was begun, except for a very slight mechanical loosening of the tickler and condenser rotating elements.

Receiving Set No. 1922-GG.-

At the end of a fifteen-minute vibration test, it was found that this receiving set was in the same condition as before the test was begun.

10. Sensitivity Measurement

In order to determine the relative sensitivities of these receiving sets measurements were made of the voltage across the telephone receivers produced by the received signals, maintaining a constant input voltage to the sets.

The measurement of this audio-frequency signal voltage in the plate circuit resulting from a radio-frequency voltage modulated at 500 cycles, induced in the antenna circuit was made by comparison of the plate circuit voltage with one available from a calibrated voltage divider supplied by an alternating-current of known value and having the frequency of the modulating voltage. An actual measurement of the two voltages was not made directly, however, but was accomplished by the comparison of the currents resulting in the output circuit of a two-stage audio-frequency amplifier. These currents were noted by means of a sensitive microammeter and crystal rectifier, coupled to the output circuit of the amplifier. Fig. 8 gives the schematic diagram of the circuits used in the measurements of sensitivity.

Having adjusted the receiving set for the best operating conditions the telephone current in the output of the amplifier was noted. The receiving set was then disconnected and the alternating-current supply was substituted for it. The value of the voltage applied to the input of the amplifier was then varied until the same current was obtained in the output circuit of the amplifier. The receiving set output signal voltage, under these conditions, was then equal to the known voltage applied to the input of the amplifier.

Measurements were made of the output voltage of each receiving set for the same input voltage at a frequency of 600 kilocycles per second (500 meters) with the tickler coupling set at minimum and then at the highest value possible without "oscillation", or generation of current by the receiving set itself. Similar measurements were made at 120 kilocycles (2500 meters). The ratio of these two voltages is a measure of the regenerative amplification of which the set is capable. The output voltages and the voltage ratios mentioned above are given in Table 10.

It is to be noted that of the data given below, the values of the voltages measured on the non-regenerating receiving set are probably the best measures of sensitivity, since in actual practice they probably will be used in that condition most frequently.

The values of the voltages measured with maximum regeneration indicate the maximum sensitivities of the receiving sets when great care has been taken in their adjustments.

The ratio of the two voltages is not a measure of the capacity of the receiving set for regeneration, since the voltage measured in the non-regenerating condition is partially due to the inherent regenerative coupling. If any interpretation is to be made of these ratios it may be assumed that they are inverse measures of the inherent regeneration of the receiving sets.

Table 10

Sensitivity Measurements

Receiving Set No.	Freq. of 600 kilocycles per second (500 meters)		Freq. of 120 kilocycles per second (2500 meters)		Ratio	
	Minimum Regeneration V_1	Maximum Regeneration V_2	Minimum Regeneration V_3	Maximum Regeneration V_4	$\frac{V_2}{V_1}$	$\frac{V_4}{V_3}$
1922-AA	(1)	(1)	(2)	0.0114	-	-
1922-BB	0.010	0.106	0.005	0.094	10	19
1922-CC	0.030	0.060	0.047	0.055	2	1.2
1922-DD	0.013	0.013	0.098	0.117	1	1.2
1922-EE	(2)	(2)	(2)	(2)	-	-
1922-FF	0.005	0.245	0.007	0.232	49	33
1922-GG	0.208 (3) 0.046 (4)	(5)	0.188 (3) 0.022 (4)	(5)	-	-

(1) This frequency not included in range covered by this receiving set.

(2) Not measured

(3) Using electron tube detector

(4) Using crystal detector

(5) Non-regenerative receiving set.

11. Selectivity Measurements

To determine the selectivity of the receiving sets, measurements were made of the sharpness of resonance when connected to a phantom antenna. The results are given in Table 11. These values were obtained by substituting in the following general formula -

$$S = \frac{\sqrt{\frac{I_r - I_o}{I_o}}}{\frac{f^2 - f_r^2}{f_r\ f}} = \frac{\sqrt{\frac{I_r - I_o}{I_o}}}{\frac{\lambda_r^2 - \lambda^2}{\lambda_r \lambda}} \qquad \text{-------------------(1)}$$

These measurements were made as follows. The receiving set was carefully tuned to the desired frequency (f_r) with minimum regeneration and the input voltage adjusted until some convenient value of current (I_r) was flowing in the telephone receiver circuit. The frequency of the generating set was then increased until the current I_r was reduced to one-half its former value. This was called I_o. The frequency was then measured and was called f. By taking I_o equal to 1/2 I_r the computation is much simplified as this makes the numerator of formula (1) equal to unity. Formula (1) then simplified to

$$S\ 1/2 = \frac{f_r\ f}{f^2 - f_r^2} = \frac{\lambda_r \lambda}{\lambda_r^2 - \lambda}$$

It is convenient to designate the value of sharpness of resonance when obtained in this manner as S 1/2.

For a more complete description of the method of making these measurements reference should be made to the Technological Paper entitled "Some Methods of Testing Radio Receiving Sets".

Table 11

Sharpness of Resonance S 1/2

Receiving Set No.	Frequency 300 kilocycles per second (1000 meters)	Frequency 120 kilocycles per second (250 meters)	Frequency 60 kilocyles per second (5000 meters)
1922-AA	11.3	10.7	6.7
1922-BB	21.5	16.1	15.4
1922-CC	4.0	1.9	(1)
1922-DD	24.5	10.9	11.7
1922-EE	14.7	17.5	18.5
1922-FF	13.3	14.0	9.1
1922-GG	12.2 (2)	10.2 (2) 30.8 (3)	(1)

(1) Frequency not included within range covered by this receiving set.

(2) Electron tube detector

(3) Crystal detector.

12. Notes on Operation

Receiving Set No. 1922-AA.-

The location and number of the tuning controls and other adjustments is fairly convenient for the reception of signals from station differing only slightly from one another in frequency (wave length). However, for arrangements of tuning involving large frequency (wave length) changes, three additional adjustments are required. The effect on the tuning of the presence of the operator's hand is rather noticeable, particularly at the high frequencies (short waves). No satisfactory control of regeneration is provided, adjustment being possible only through change of the filament current. At normal filament current the receiving set generates steadily. It is, therefore, unsuitable for the reception of radio telephone or damped signals.

Receiving Set No. 1922-BB.-

The arrangement of tuning controls is rather inconvenient. The number of adjustments required for slight changes in tuning is small and for large changes the replacement of the interchangeable inductors requires considerable time. The effect of the operator's hand on the tuning is particularly noticeable especially on the high frequencies (short wave lengths). When a change is made in the coupling there is considerable change in frequency (wave length). By proper selection of coils it is possible to secure a smooth adjustment of regeneration. The performance in this respect is especially satisfactory at the low frequencies (long waves).

Receiving Set No. 1922-CC.-

The arrangement of tuning controls is convenient for manipulation the number of adjustments required being small. The tuning is, however, subject to changes in position of the hand of the operator. Through the middle part of the frequency (wave length) range covered by this set, the control of regeneration is unsatisfactory.

Receiving Set No. 1922-DD.-

The controls are placed at convenient points on the receiving set panel. On account of the interdependence of frequency, coupling, and regeneration controls, successive readjustments are necessary in retuning to a new frequency. The absence of shielding results in quite noticeable changes in tuning as the operator's hand is moved from one control knob to another. Satisfactory regeneration control is only possible through the middle part of the frequency (wave length range covered by the set.

Receiving Set No. 1922-EE.

The tuning controls on this receiving set are fairly conveniently arranged, though for large changes in frequency (wave length) where

the interchangeable inductance coils must be replaced, their location makes this operation rather slow. Changes in coupling make necessary further readjustments of the tuning, though the effect of the operator's hand on the tuning is not excessive. The proper adjustment of regeneration is rather difficult.

Receiving Set No. 1922-FF.-

The tuning controls are compactly arranged and easy of access. The general panel arrangement is, however, reversed from that which is usually found, the antenna connection being at the right rather than at the left. The number of tuning adjustments required is small but the effect of the operator's hand is rather troublesome. A change in the regeneration control makes necessary a readjustment of tuning where weak signals are being received. Regeneration is conveniently controlled except at the highest frequencies (shortest wave lengths).

Receiving Set No. 1922-GG.-

The tuning controls are rather widely spaced over the large panel and in this respect are somewhat inconvenient. The tuning adjustments may, however, be quite quickly and simply accomplished. The test buzzer is useful when the crystal detector is used. Adjustment of contact on the detector is very convenient. This set is non-regenerative.

13. Performance Tests

Purpose of Performance Tests.- The purpose of the following tests was to study, under actual working conditions, the effectiveness of several receiving sets and to secure information that might enable a more extensive performance test procedure to be outlined. These tests were made by Messrs. C.M.Jansky, Jr., H.C.Forbes and other at the University of Minnesota, Minneapolis, Minn.

General Outline of Procedure.- Receiving set No. 1922-CC and receiving set No. 1922-M * were sent to the University of Minnesota station. The two sets were installed in the University station in such a way that they might be alternately connected to the antennas. The receiving set that had been generally used at the station was of the short-wave coupled type, tuned with continuously variable inductors. This receiving set was also used for taking

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* Laboratory tests on this receiving set are described in Bureau of Standards Letter Circular 102.

observations. Each of the three sets had its own detector tube but the same two-step amplifier was used with all of them. This was a Signal Corps SCR-72 amplifier. Hereinafter the University station receiving set is referred to as set "SS"and 1922-CC set as set "CC" and the 1922-M set as set "M".

The three receiving sets were used for general experimental station work during the period from May 17 to May 29,1922 according to the procedure which will be described. The operating staff at that time consisted of eight operators who stood watch in the station four evenings per week in groups of two. Operators went on duty at 10 p.m. during the evenings on which the station was in operation.

The period from 10 p.m. to 10:30 p.m. was used in most cases for making measurements of signal and stray audibility. In securing the data on signal strength, the audibility of from 5 to 20 different stations was averaged. Stray audibility on damped wave stations was taken with the set adjusted for regeneration while stray audibility for continuous-wave stations was taken with the set adjusted for oscillation. The results given in Table 12 are the averages of signal to stray audibility for five different evenings of operation.

Beginning at 10:30 p.m. and continuing until 12 M (midnight) or 1 a.m., the operators used sets SS, CC and M in turn for periods of one-half hour duration each in such a way as to permit a comparison of the relative signal strength of stations heard on each, as well as the selectivity and ease of tuning of each. The next evening the order of use of these various sets would be changed in such a way as to equalize the conditions throughout the tests so far as possible. Thus, if an operator should start with set SS at 10:30 p.m. the first night using CC and M the second and third periods respectively, the next operator on the following night would use set CC the first period and set M and SS the succeeding periods, etc. Record was kept of the number of hours spent in the use of each set together with a list of the stations heard and communicated with. A compilation of these data is given in Table 13. Table 13 is the result of 12-1/4 hours operation of set SS, 6-3/4 hours operation of set CC and 4 hours operation of set M. The value of these data is somewhat decreased because of the unequal length of operation for each receiving set.

The data were taken entirely during the course of communication with experimental and amateur damped and undamped wave transmitting stations scattered throughout the United States, and the conditions were practically identical with the working conditions of any experimental or amateur station engaged in radio telegraph communication with other stations of a similar character. The University station was equipped with a damped wave transmitting set putting approximately 250 watts in the antenna and an undamped wave transmitting set putting about 100 watts in the antenna. These two sets were used in maintaining the communications mentioned in Table 13.

It should be borne in mind that all communications with other stations were entirely without the aid of prearranged schedules. The data on communications maintained is of importance because of the fact that it is possible to hear a distant station with sufficient intensity to secure the call letters of that station with a comparatively non-selective receiving set but the use of a fairly selective receiving set is necessary in order to maintain communication with that station through a considerable amount of interference. The fact that there were, at the time of the tests, approximately 125 amateur stations located within a radius of ten miles of the University station is of importance in judging the amount of interference to be met with in normal operation.

Conclusions from Statistical Data.- Whereas the number of observations entering into the compilation of the data given in Table 13, is probably not sufficient to warrant sweeping conclusions, certain deductions are of interest particularly as they are verified by the independent observations and opinions of the operator and the laboratory tests previously made.

It will be noticed that the audibility of strays received of set SS, the coupled set, when adjusted for the reception of damped waves, is somewhat less than that of either set CC or M. This is also true when receiving continuous waves but not to as great an extent. While the signal audibility on set SS of damped waves is almost twice that of sets CC and M, the audibility, in set SS, of continuous wave signals is less than that in either CC or M. In every case, however, the signal-stray ratio is best on set SS, the coupled set. This would seem to indicate a certain advantage in favor of the coupled set in the elimination of strays.

It will be noticed that the average number of stations heard per hour on sets CC and M is 12 and 13.2 respectively while the average for set SS is only 9. On the other hand, the average numbers of communications per hour for sets CC and M are 1.03 and 1.25, respectively, while that for set SS is 1.39. This would seem to indicate that although the ease in tuning of the single-circuit receiving sets CC and M enables an operator to hear a relatively greater number of stations within a given time, the greater selectivity of the coupled set makes it possible to hear a distant station with sufficient freedom from interference to enable communication to be maintained in cases where a single-circuit receiving set would not. On the other hand it is to be remembered that set SS was operated two to three times as long as sets CC and M.

Summary of Operators' Opinions.- In addition to the statistical data given above, meetings of the operating staff were held from time to time at which the relative merits of the various receiving sets were discussed. A summary of these opinions is given in Table 14. In obtaining information from the operators it was found that very little difference of opinion on the relative merits of the

receiving sets existed and where some difference of opinion did exist it was on points of minor detail. Certain facts brought out at these conferences are worthy of special attention.

In the opinion of the operators, set SS was the best for all-around traffic work. It gave the best signal-to-stray audibility ratio, and was most free from extraneous noises in its operation. On the other hand, the received signals were somewhat weaker than on sets CC and M, also this set was the most difficult to tune, and the capacity effects owing to lack of shielding, were the most troublesome.

Signals were louder on set CC than set SS. Set CC was also easy to tune and showed very little capacity effect. On the other hand, CC was very noisy as compared to SS, was non-selective for damped waves, brought in strays much louder than SS, and would not generate over its entire range with a large antenna.

Continuous-wave signals were stronger on set M than on set SS. M was less susceptible to strays than CC but more so than SS. M was also practically free from capacity effects of the operator's hand. It was found that set M was more noisy in operation than SS, though better than CC in this respect. The tickler control on set M, which operates by steps, did not make possible the desirable fine adjustment of regeneration.

Table 12

Data on Audibility Measurements

Averages of observations on five separate nights of operation by five different operators

Damped Waves and Phone (Sets adjusted for regeneration)	Set SS	Set CC	Set M
Average signal audibility	1970	1060	1040
Average stray audibility	1030	1290	1830
Signal-to-stray ratio	1.9	0.83	0.57

Continuous-Waves (Sets adjusted to generating Condition)	Set SS	Set CC	Set M
Average signal audibility	1980	2550	2190
Average stray audibility	825	2980	1070
Signal-to-stray ratio	2.4	0.86	2.0

Table 13

Data on number of stations and total distance in miles computed on the basis of "Per Hour of Operation." Total distance in miles is calculated by rating each station according to its distance. Continuous and damped waves grouped together in this table.

	Set SS	Set CC	Set M
Stations logged per hour	9.0	12.0	13.2
Total distance in miles, per hour	2580	4000	5500
Communications per hour	1.39	1.03	1.25

Table 14

Summarized opinion of operating staff on order of desirability of sets SS, CC and M from the following standpoints.

Selectivity (Damped-wave and modulated continuous-wave signals)	SS - M - CC
Selectivity (Continuous-wave signals)	SS - M - CC
Signal Strength (Damped-wave and modulated continuous-wave signals)	SS - M - CC
Signal Strength (Continuous-wave signals)	CC -(SS (M
Signal to stray audibility ratio	SS - M - CC
Freedom from extraneous noises	SS -(CC (M
Ease of Tuning	(CC - SS (M
General all-round traffic work	SS - M - CC

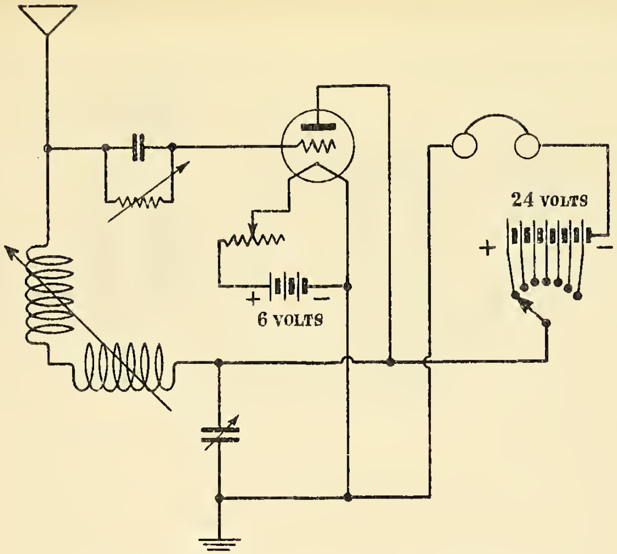

FIG. 1. CIRCUIT DIAGRAM OF RECEIVING SET NO. 1922 AA.

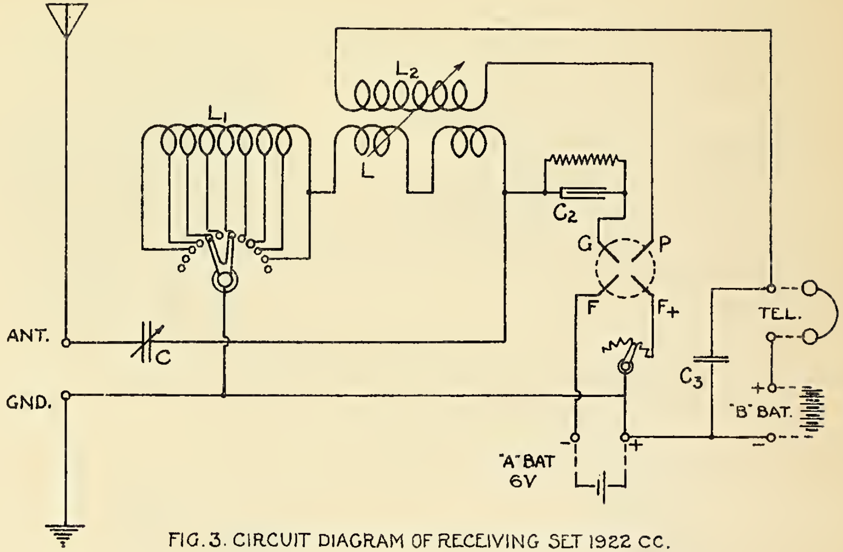

FIG. 3. CIRCUIT DIAGRAM OF RECEIVING SET 1922 CC.

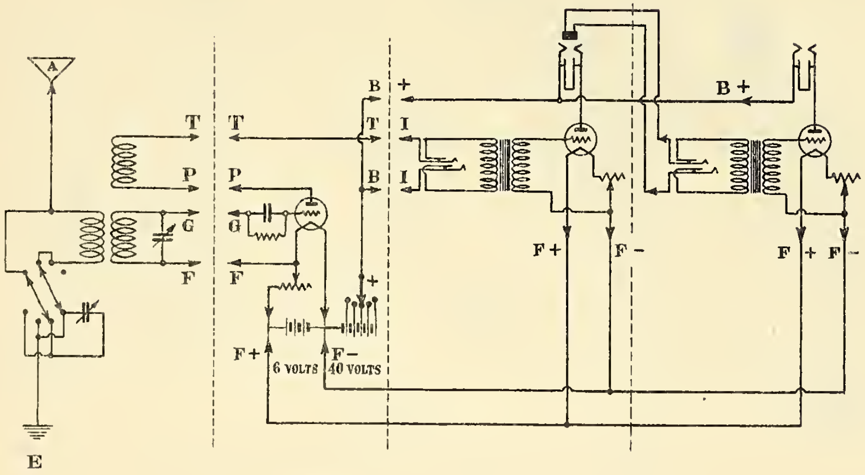

FIG. 2. CIRCUIT DIAGRAM OF RECEIVING SET NO. 1922 BB.

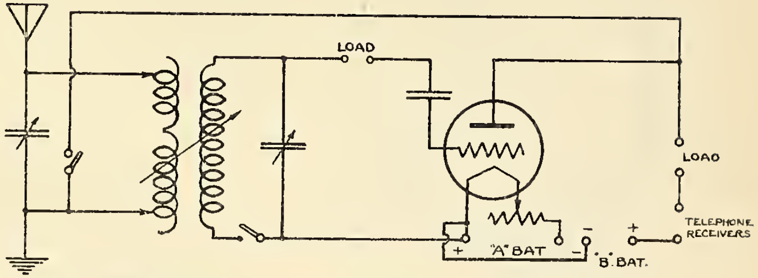

FIG. 4. CIRCUIT DIAGRAM OF RECEIVING SET NO. 1922 DD.

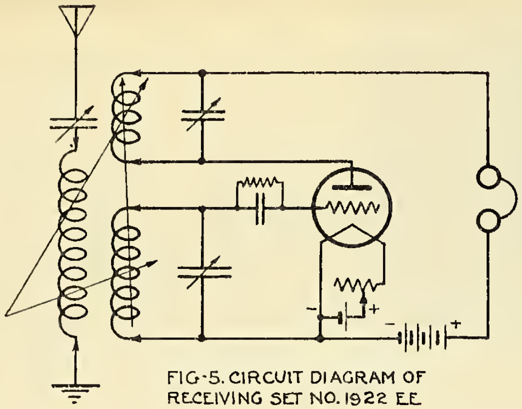

FIG-5. CIRCUIT DIAGRAM OF RECEIVING SET NO. 1922 EE.

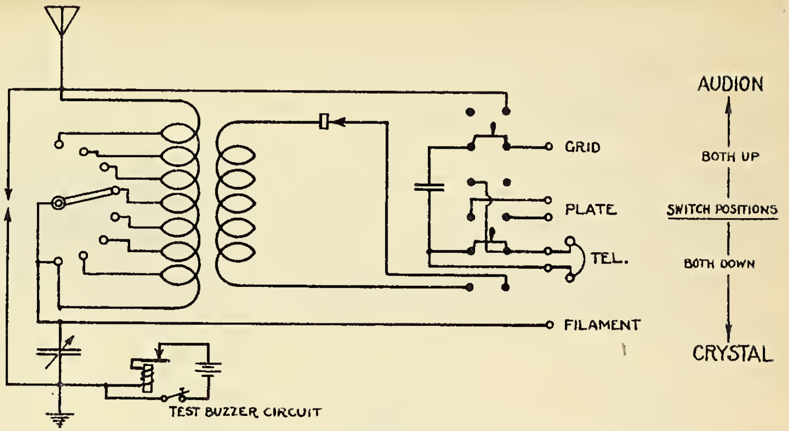

FIG-7. CIRCUIT DIAGRAM OF RECEIVING SET NO. 1922 GG.

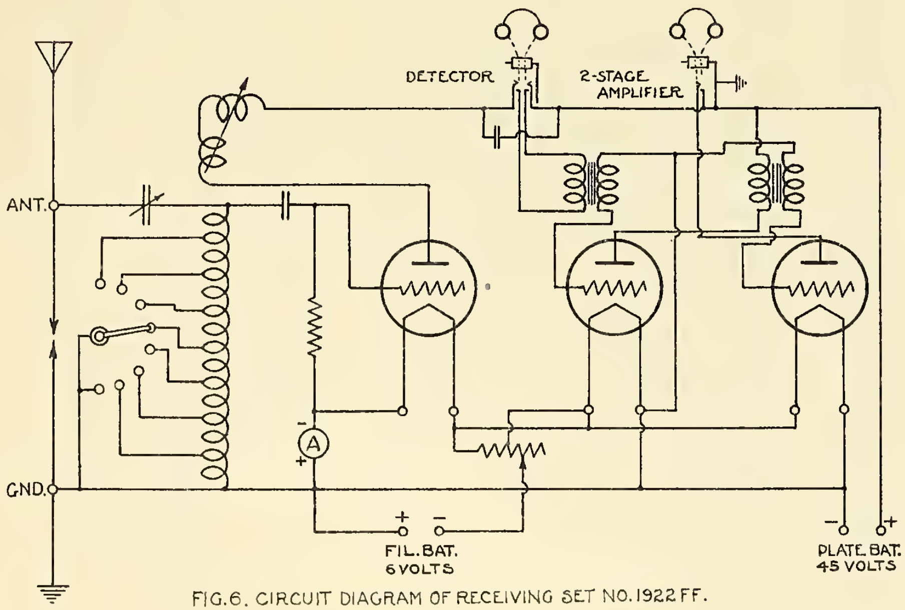

FIG. 6. CIRCUIT DIAGRAM OF RECEIVING SET NO. 1922 FF.

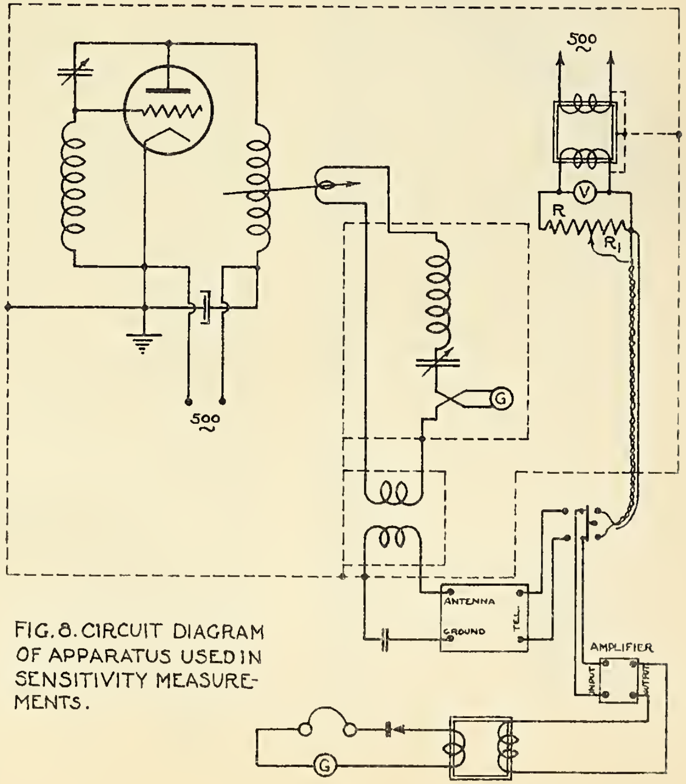

FIG. 8. CIRCUIT DIAGRAM OF APPARATUS USED IN SENSITIVITY MEASUREMENTS.